INFORMATION TECHNOLOGY, COMPUTER SCIENCE, AND MANAGEMENT



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Revisiting computer modeling

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Introduction. Modeling serves as a methodological basis for modern science and a tool for cognitive activity. It can be considered as a thinking activity mediated and optimized through information models. In this case, logical operations of cognition and simulation techniques are applied to the information.
Materials and Methods. The scientific research results on how knowledge is formed, stored and processed in a person's memory, how they interact with information representations are studied and summarized. Information models used in various subject domains are analyzed. The provisions on rational ways of presenting information under modeling are formulated, and computer tools for constructing such representations are indicated.
Results. Methods and techniques for visualizing information on the object under study are specified. Software tools and services providing visualizations and research modeling procedures are given.
Discussion and Conclusions. The results obtained can be used to optimize modeling procedures. Images, structures, relationships and connections of the object under study are visualized in special programs with the help of the described methods and techniques. They, in turn, mediate the process of mental modeling and broaden the basis for its implementation.

Keywords: modeling, model, information technologies, information model, computer model, information representation, computer simulation techniques, computer modeling environments.

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Introduction. Modeling is used for theoretical and practical research of objects, processes, phenomena. It has a general scientific character, is an objective, universal method of cognition and is used to study animate and inanimate nature. Modeling serves as a methodological basis of modern science and a tool for cognitive activity. Development of computing and information technologies contributes to the success of information modeling. This approach involves the application of research procedures to formalized information on the object of study replacing or reproducing the object. An information model is becoming a modern tool for solving various problems using information technologies and a link connecting any subject area with informatics.

Modeling is characterized, on the one hand, by a variety of models used (Fig. 1), on the other, by a variety of means of constructing and studying them.

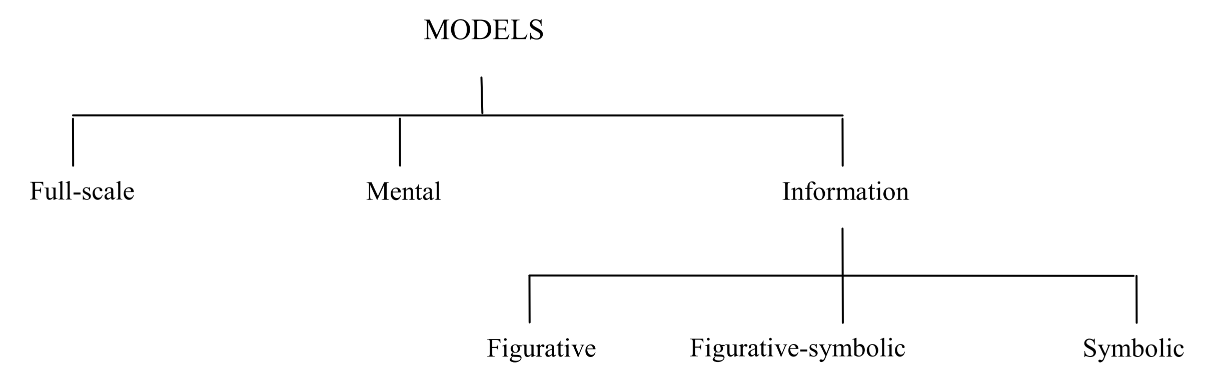


Fig. 1. Classification of models by presentation form

Summarizing many definitions, by the term "information model" [1], we mean information that describes the essential properties of an object and its links; it is formalized from the point of view of the research goal and recorded on storage medium. This definition provides clear identification of the close relationship between informatics and modeling and analyzing information technologies as modern simulation tools. Information can be presented in different forms; therefore, computer sciences [2] study various information models: verbal, graphic, mathematical, tabular, algorithmic, imitation, etc. In the cognitive theory, any model can be considered informational if it is included in the information process of cognition.

Let us consider the stages of information modeling.

The first stage is the analysis of the object and its links, which involves the execution of logical operations of cognition. These are comparison, classification, systematization, generalization, concretization, inference, idealization (construction of abstractions). Such modeling techniques as observation, analysis, synthesis, analogy, hypothesizing, formalization, are used.

The second stage is practical actions. This is actually modeling (building a model) and operations with it (rebuilding, modifying, model implementation, experimenting, interpreting, verifying, replacing). Actions with model elements include subtraction, addition, and complementation [1].

The third stage is the construction of algorithms for the implementation of the model in a specific subject domain, the involvement of information technologies to work with the model.

"These three stages reflect, on the one hand, the major stages of cognition: sensory — rational — activity; on the other hand — the classical triad of information modeling: information — model — algorithm" [3].

A computer model is built on the basis of the information model. Computer simulation is a combination of hardware and software tools and technologies for working with these models. S.A. Beshenkov emphasizes that "it is quite possible to talk about computer modeling as a special type of information modeling" [4]. Information technologies used to work with information models determine the type of the latter (figurative, figurative-symbolic and symbolic). Their classification is shown in Fig. 2.

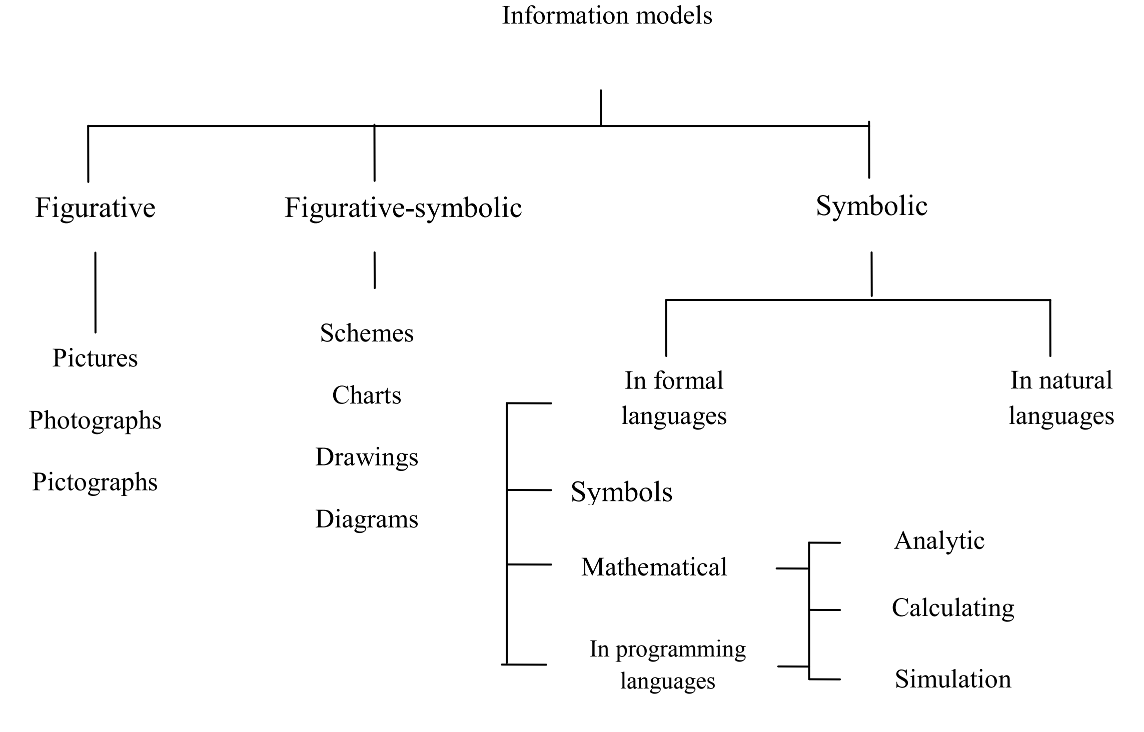


Fig. 2. Classification of information models depending on information technologies

Let us list some computer modeling tools:

— visual — hardware and software tools and technologies for working with computer graphics, video images, animation, sound, virtual reality;

— verbal — text editors and processors, optical character recognition systems, publishing systems, hypertext markup languages;

— mathematical — electronic calculators, software packages for mathematical calculations, programs for analytical transformations, calculation and information systems, virtual laboratories;

— modeling systems — visual modeling packages, simulation systems, programs for generating fractal images, spreadsheets, presentation packages, computer-aided design (CAD), geoinformation systems;

— programming languages and systems [5].

Simulation-related tasks are solved in computer simulation environments [5]. This implies specialization, interconnection of modules and modeling language, and increases the speed of research. For example, CAD is the most important means of building interconnected models within the project of the object being created. The modeling environment consists of several modules that enable to create a figure, a drawing, a 3D model of the future object, and to perform computer experiments on the model determining the possible properties of the object and predicting probable events, in the modeling environment.

According to S.I. Arkhangel'skii, modeling as a form of study provides the most clearly expressed connection between experimental data and theoretical views. This allows us to consider the model as a certain sequenced relationship of conceivable (theoretical) and experimental information based on the selection of the studied aspects and features of the object through simplification, or complication, or abstraction [6]. Here, theoretical information is information that represents the object of research, i.e., selected and formalized from the point of view of the study objective. This is the basis of mental and symbol-mediated operation. A researcher receives empirical information in the process of modeling, studying theoretical data, which are the approximate basis of his thinking activity. In other words, in the process of modeling, a chain of mental models is created. Some of them are fixed in symbolic form. Until new knowledge is obtained, logical and modeling operations based on the constructed symbolic representations are performed. When constructing a representation of the object of research, objects of operation for thinking are created; the work of thinking aimed at studying the model is stimulated. At the same time, knowledge on the object is analyzed, refined, changed and deepened.

Materials and Methods. Simulation is a multistage, cyclical procedure. It is impossible to build, study a model of an object and gain knowledge at once. In the process of modeling, it is required to repeatedly apply logical operations of cognition and modeling techniques to information. The task of this study is to highlight the techniques and methods for presenting information that support the execution of logical modeling procedures. It is also necessary to note the computer tools, the use of which activates and rationalizes the process of information modeling. To solve this problem, generalized scientific and pedagogical experience and practical knowledge of modeling are used.

For information models to effectively help to gain knowledge in the modeling process, it is required:

— to know and apply the patterns of handling ideas and knowledge;

— to use computer technologies to form representations.

At the same time, it is important to take into account scientific data on how knowledge is formed, stored and processed in a person's memory, how they interact with representations of information.

There are several hypotheses about the representation of information in memory.

According to the hypothesis of double coding, information can be encoded and stored in one of two or both systems — verbal and figurative. This position is supported by the neurological and behavioral data [7].

According to the conceptual propositional hypothesis, information is stored in an abstract propositional format that defines objects, events, and their relationships.

The radical theory of images assumes that some information is presented only in the form of images [7]. N. I. Kolodina believes that all information perceived by a person is encoded in consciousness simultaneously through sight, hearing, smell, touch, and experienced emotions, and is presented in the consciousness of an individual in the form of units of knowledge called mnemonic units of knowledge (MUK). These units are structured in consciousness according to the channels of perception and are constantly being re-formed, forming more and more new connections among themselves. N. I. Kolodina offers a model of consciousness as a structured set of units of knowledge. The formation of thought formations in this model occurs as a result of the interaction of knowledge units with the surrounding reality. Then MUK are integrated with each other according to the laws of a single logical-thinking base [7].

In the case of activating only one unit located in any zone of the structure, there is a chain activation of other units of knowledge that have stable connections with the activated unit [8]. This hypothesis has something in common with the connectionist description of the work of the speech mechanism. It is based on the research results of information processing by the brain. In this case, the forms of knowledge are represented as a network structure. The network consists of nodes and connections between them (connectionism — from the English “connect”: connection). The effective functioning of the network system provides the distribution of activation [9, 10].

N. I. Zhinkin put forward the hypothesis for the existence of a universal subject code (USC) in the human mind. USC is the language of intelligence, the basic component of thinking. It is the language of schemes, images, imprints of reality (tactile, olfactory), kinetic (motor) impulses, etc. The USC is the language in which the primary recording of personal meaning takes place [9]. USC is a code by which information turns into “primary knowledge”, sets of MUK, which can be compared to representations from cognitive linguistics: representations include

representations proper, images and concepts, as well as associated assessments and connotations. Therefore, on the one hand, representations are mental models; on the other, they are the subjective basis of objective knowledge. Representations are formed in the process of mental modeling of reality. According to G. Frege, as noted by V. V. Krasnykh, a representation is an internal image of an object that arose from memories of sensory impressions [9].

Research Results. Summarizing the above scientific judgments, it is possible to formulate provisions on the ways of representing theoretical information in models and denote the computer tools for such constructions.

Primary knowledge is actually ideas, images, concepts and evaluations. For the formation of ideas, all channels of information are important: visual, auditory, olfactory, gustatory, tactile, and kinesthetic. According to the experimental data, visual coding occurs earlier than acoustic and semantic coding [7]; therefore, under the formation of knowledge, the methods of visual modeling of information are basic and supplemented by others.

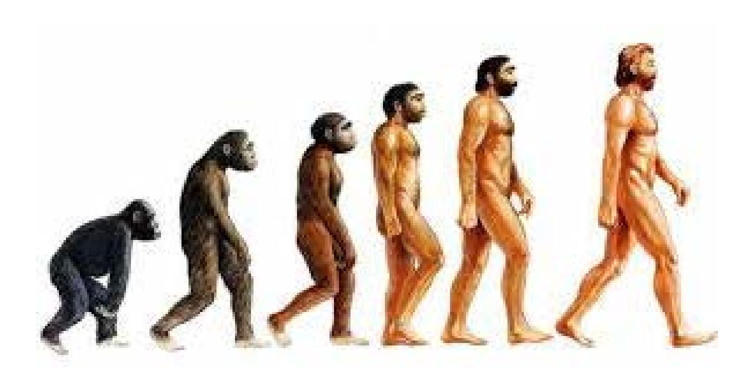
Pictures, color, representation of details are of great importance in the following ways of transmitting information: lens and the Fish Eye technique (Adobe Photoshop, Corel Draw, Inkscape, Blender), graphic simplification, maps, colored histograms (Paint, Word, Excel, Corel Draw, Inkscape, etc.), visual dictionary (Word, Excel, HTML, PHP).



a)

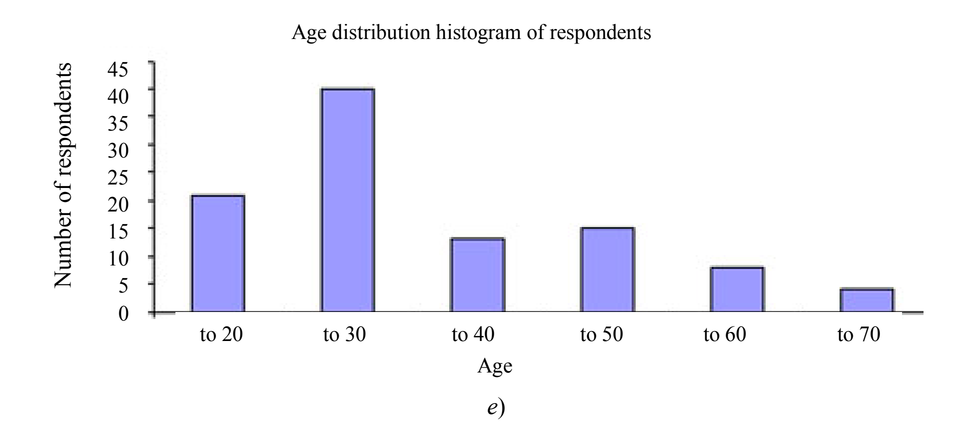


b)

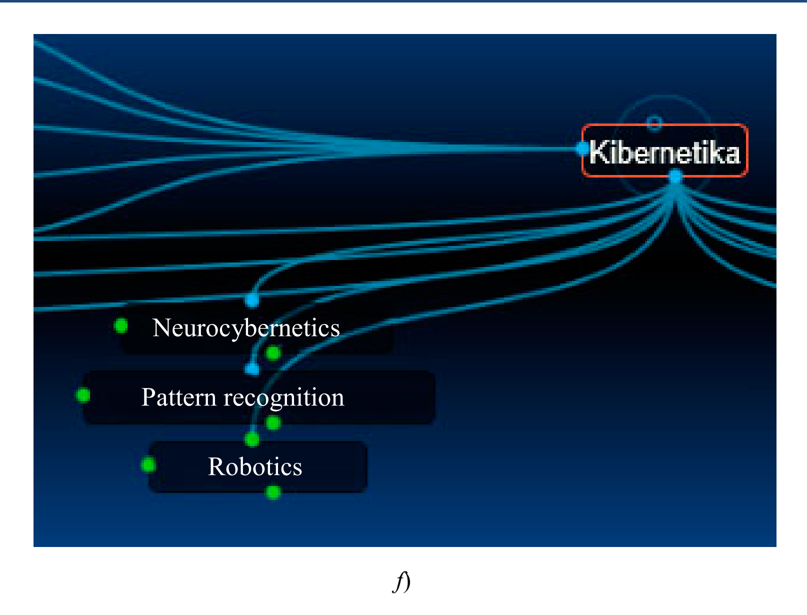


c)

d)


Age distribution histogram of respondents
Number of respondents
0
5
10
15
20
25
30
35
40
45
to 20
to 30
to 40
to 50
to 60
to 70
Age

e)



f)

Fig. 3. Examples of information presentation: lens (*a*), Fish Eye (*b*), graphic simplification (*c*, the concept of “evolution” is presented); map (*d*), histogram (*e*), visual dictionary (*f*)

The most important are the verbal and figurative coding systems; therefore, most ways of presenting information include at the same time pictures, signs, words, texts. It can be a cloud of tags, words (Wordle, Tagul, Many Eyes, Word it Out, Togxedo-Creator), mental maps (MindManager, Mindmeister, FreeMind, XMind), maps and cyclic schemes (Corel Draw, Inkscape, Excel, Word, Adobe Flash), etc.

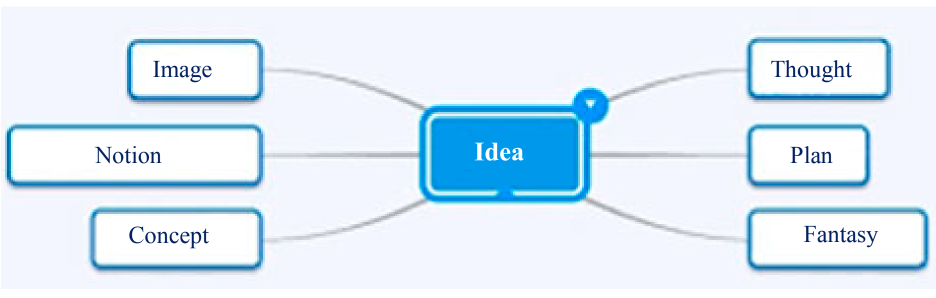


a)

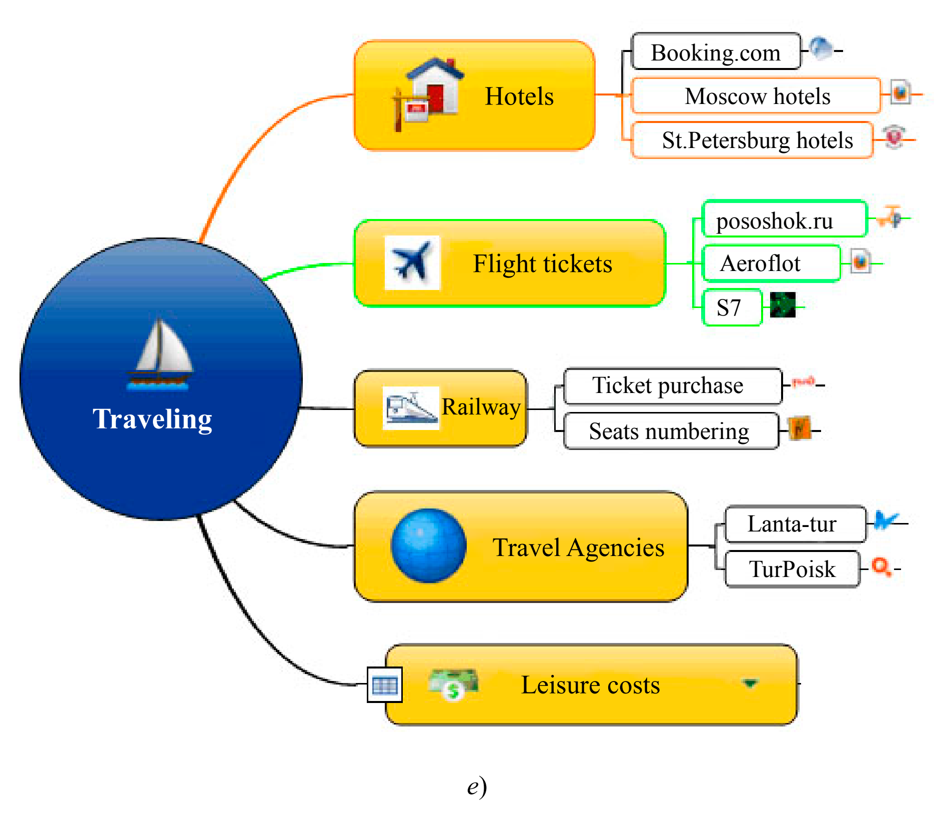
b)



c)



d)

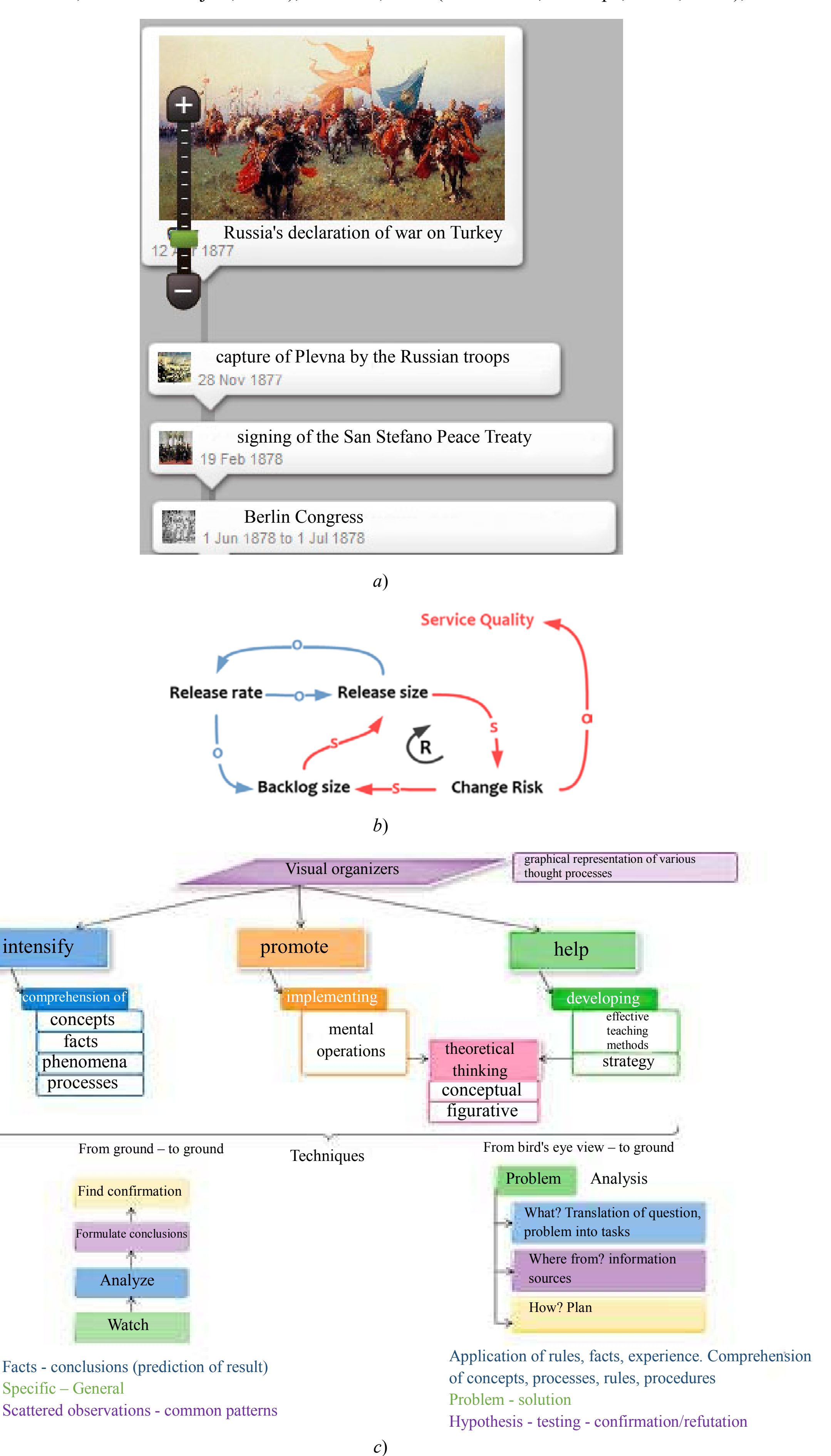


e)

Fig. 4. Examples of information presentation:
clouds of words and tags (*a, b*); cyclic scheme (*c*); mental maps (*d, e*)

Knowledge storage involves fixing data about objects, events and their relationships. The following ways of presenting data correspond to this format: timelines (Dipity, ClassTools, Timerime), causal chains (Paint, Word, Corel

Draw, Inkscape), inductive towers (Bubbl.us, Cacoo.com services), Gantt affinity diagrams (SchedRoll, Gantt Designer, Mindjet JCV Gantt Pro, Microsoft Project, Excel), Ishikawa, Venn (Corel Draw, Inkscape, Excel, Word), etc.



a)

b)

c)

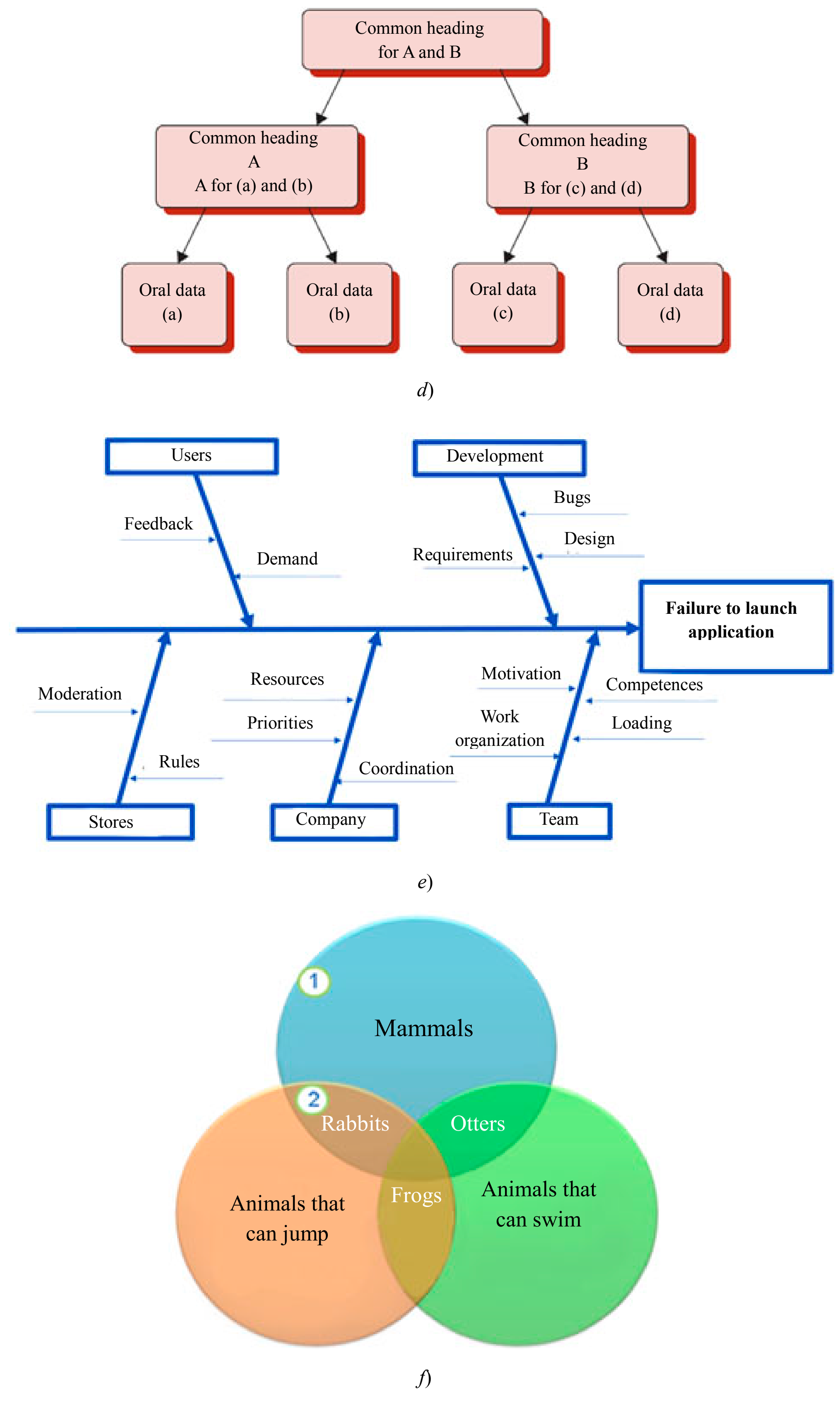
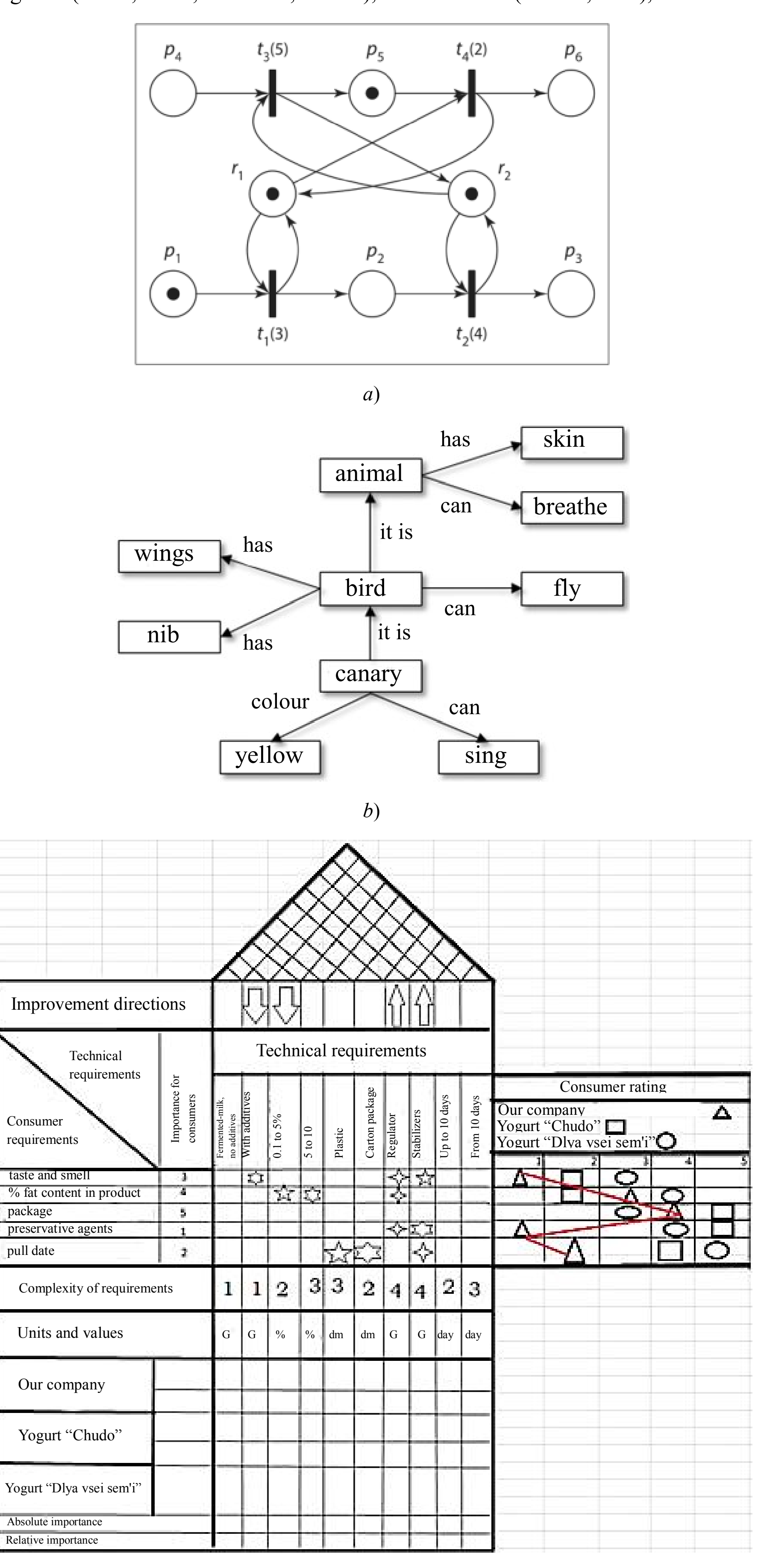


Fig. 5. Examples of information presentation: timeline (*a*), causal chain (*b*), inductive tower (*c*), affinity diagram (*d*), Ishikawa diagram (*e*), Venn diagram (*e*)

Units of knowledge in consciousness are structured in accordance with the channels of perception; they are constantly re-formed and form new relationships. Thought formations are created as a result of the interaction of units of knowledge and the surrounding reality. It is very important to rely on realistic and dynamic representations of research objects when solving complex problems. Under modeling, to present information about an object, you should use multimedia and virtual reality tools: photo, video, sound, animation (Gimp, Adobe Flash, HTML5, video players, etc.); three-dimensional representations (VRML. Blender, etc.).

All forms of knowledge appear in the form of a network structure that functions using a propagating activation mechanism: Petri nets, semantic nets, House of Quality, hyperbolic trees, pyramids (Corel Draw, Inkscape, Excel, Word), data flow diagrams (Excel, Word, MS Visio, BPwin), visual tutorial (HTML, PHP), etc.



a)

b)

c)

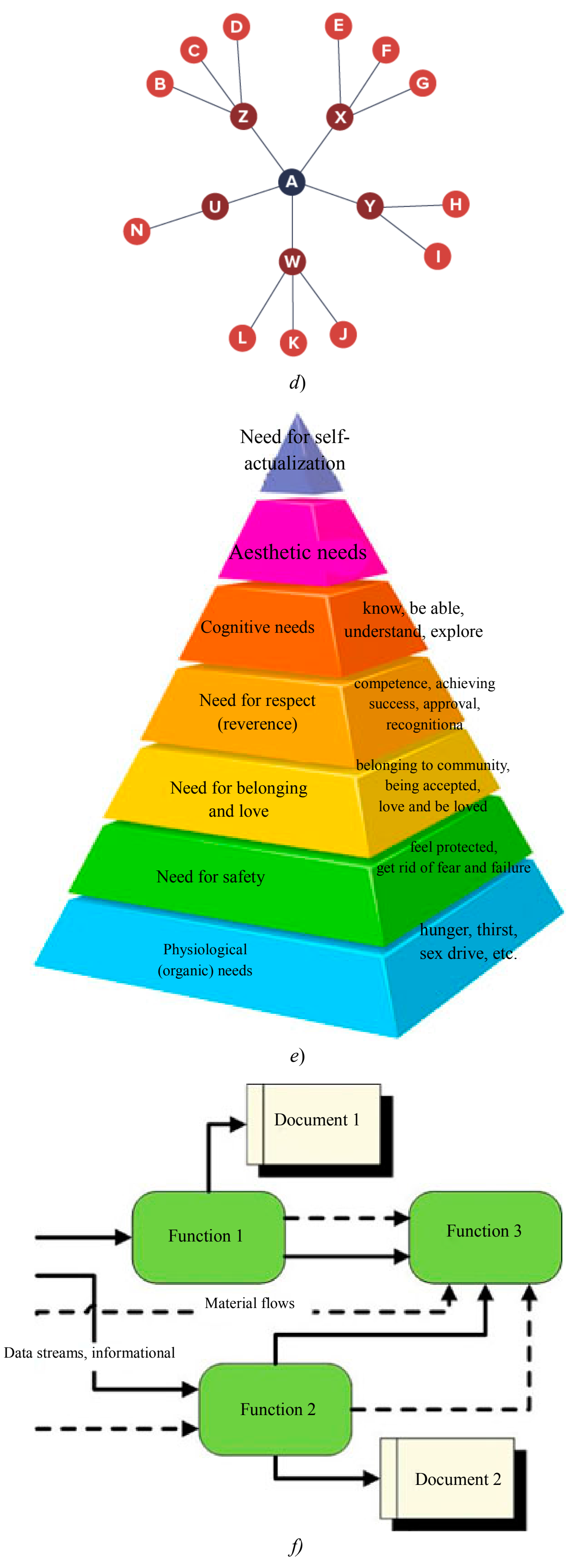
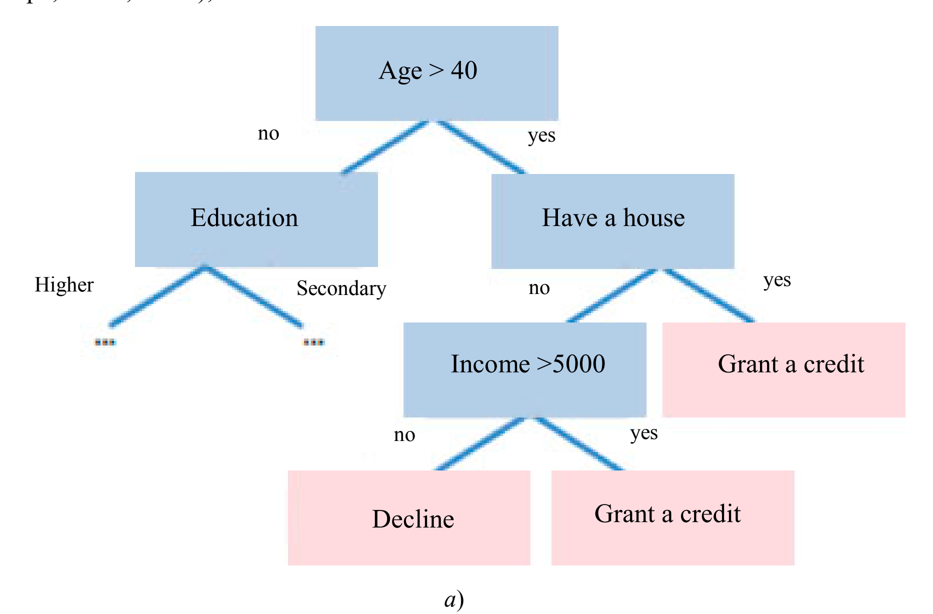
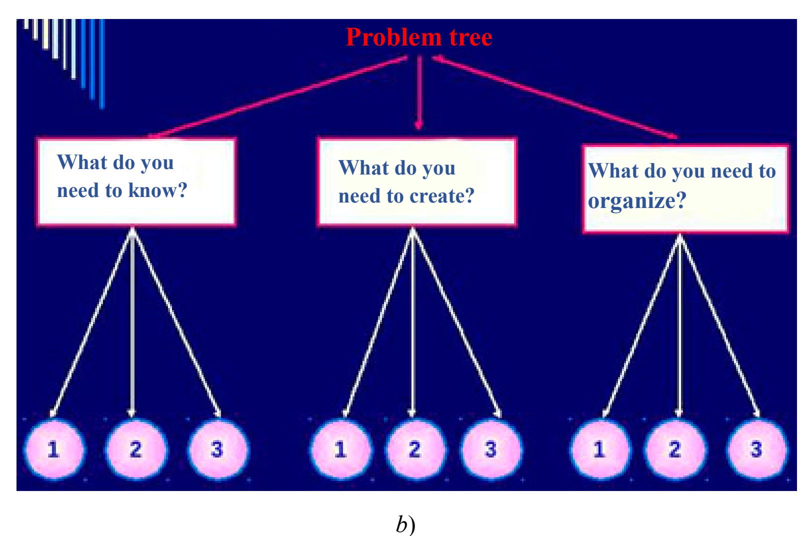


Fig. 6. Examples of information presentation: Petri net (*a*), semantic net (*b*); House of Quality (*c*); hyperbolic tree (*d*), pyramid (*e*), data flow diagram (*f*)

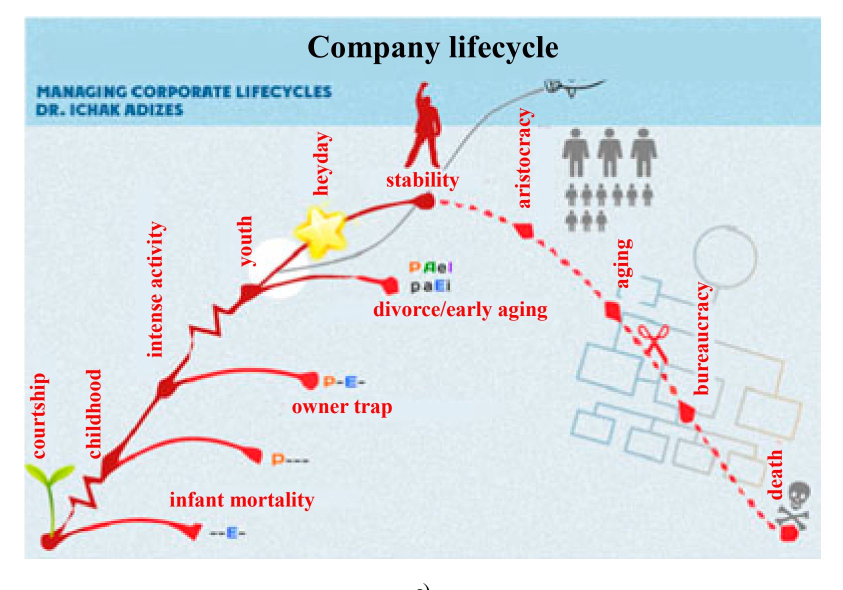
The language of intelligence is the language of schemes, images, imprints of reality (tactile, olfactory), kinetic (motor) impulses. In this vein, decision and problem trees, life cycle and reasoning diagrams, data funnels are built (Corel Draw, Inkscape, Excel, Word), etc.



a)



b)



c)

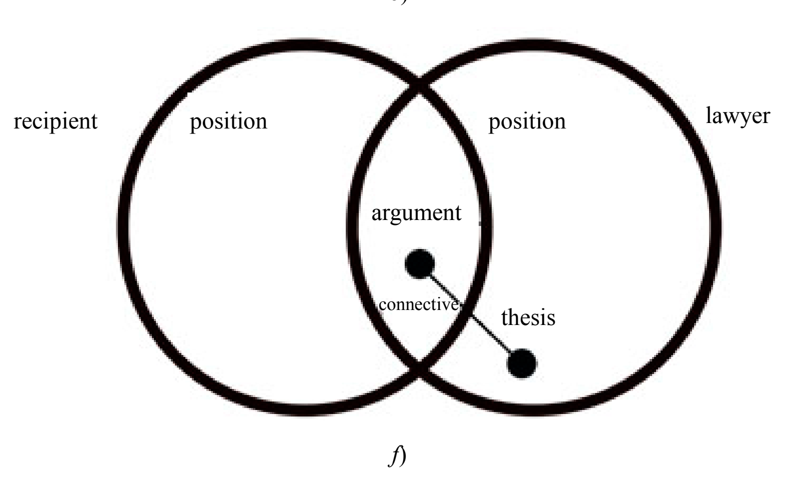
Purchase funnel in B2B

100	Target customers
76	Manager got through
19	There is interest
8	Meeting and negotiations
4	Bill is paid

d)



e)



f)

Fig. 7. Examples of information presentation: decision tree (*a*), problem tree (*b*); lifecycle (*c*); funnel (*d*), argument-slide (*e*), argumentation (*f*)

So, the methods of graphical visualization of information, widely used in various subject domains, are based on scientific theses on the formation of primary knowledge, its connection and storage in human memory. These methods mediate the process of mental modeling. They help to create and save images, structure, relations, links of the studied object for modeling procedures on information medium. At the same time, it becomes possible to perform modeling actions not only individually, but also in a team using the experience of team members, which rationalizes the modeling process. At this, it is important to use software and services to create visualizations that will help in modeling research.

To increase the efficiency of modeling, graphic visualization methods adequate to the tasks, as well as IT-tools for data presentation are used: multimedia systems, computer visualization and decision support systems, expert systems, project management systems, cognitive modeling systems, simulation environments, computer games, agent-based modeling, etc.

Conclusion. The informational and logical aspects of modeling combine three key categories of cognition — information, representation, knowledge. Actions with models include search, selection, presentation and processing of available information on the object of research, on whose basis you can get new knowledge about it. For this, the means of information processes and technologies are used. Computer simulation plays a key role. Optimization is an essential function of the mental component of modeling as the fundamental basis for the model way of cognition. In mental modeling, an image is built on the basis of sensory perception, to which the operations of analysis, synthesis, comparison, abstraction, generalization, systematization, classification, and logical operations are applied. This provides transforming a sensory image into a logical model of cognition. Through mental modeling, a person first forms an information model of the object of research, and then studies it by constructing a number of interrelated mental representations and the corresponding information models.

The application of computer tools for presenting information enables to optimize mental activity. At the same time, various parameters and links of the studied object are visualized. Modern computer simulation tools complement, extend, and modify traditional simulation tools.

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